

The Joint Center for Satellite Data Assimilation, Progress and Plans

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Director, JCSDA

Overview

- Introduction
- JCSDA, its mission and partners
- Satellite data, NWP and societal benefits
 - in the JCSDA
 - elsewhere
 - measuring the impact
- Outlook and plans, challenges

JCSDA mission:

...to accelerate and improve the quantitative use of research and operational satellite data in weather, ocean, climate and environmental analysis and prediction models.

JCSDA Science Priorities

- Radiative Transfer Modeling (CRTM)
- Preparation for assimilation of data from new instruments
- Clouds and precipitation
- Assimilation of land surface observations
- Assimilation of ocean surface observations
- Atmospheric composition; chemistry and aerosol

JCSDA Partners

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

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graph TD; A["Agencies Executives  
NASA, NOAA,  
Department of the Navy, and  
Department of the Air Force"] --> B["Management Oversight Board (Rotating Chair)  
NOAA/NWS/NCEP  
NASA/GSFC/Earth Sciences Division  
NOAA/NESDIS/STAR  
NOAA/OAR  
Department of the Air Force/Air Force Director of Weather  
Department of the Navy/N84 and NRL  
DoD/USN/NRL"]; B --> C["JCSDA Executive Team  
Director  
Agency Deputy Directors  
Chief Administrative Officer"]
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JCSDA Executive Team
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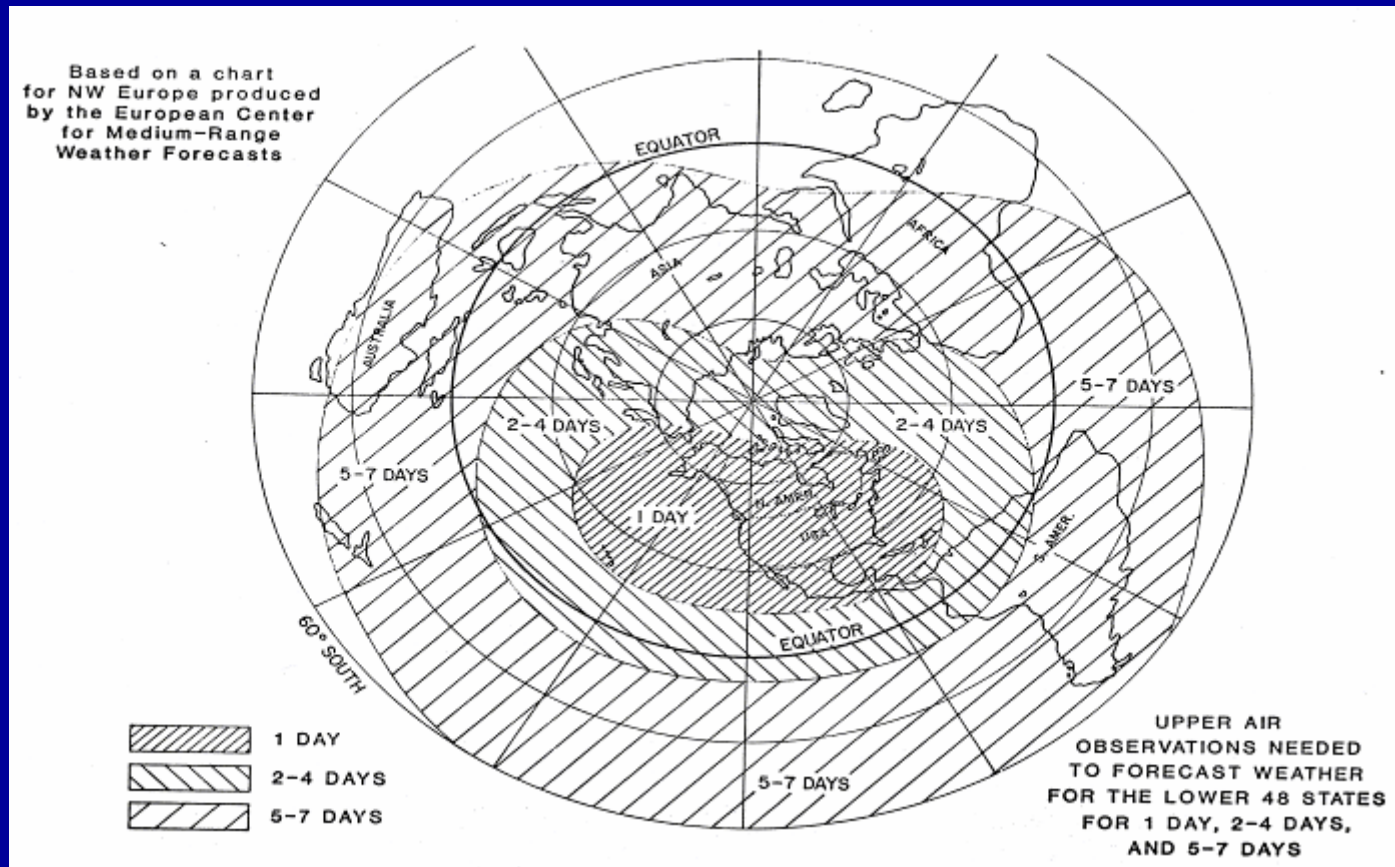
JCSDA Mode of operation

- Directed research
 - Carried out by the partners
 - Mixture of new and leveraged funding
 - JCSDA plays coordinating role
- External research
 - NOAA-administered FFO
 - ~\$2M/year available => revolving portfolio of 15-20 three-year projects
 - Open to the broader research community

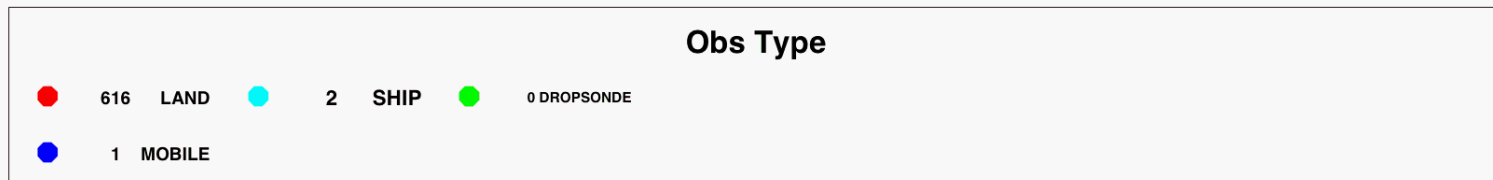
Major Accomplishments

- Common assimilation infrastructure at NOAA and NASA
- Community radiative transfer model
- Common NOAA/NASA land data assimilation system
- Interfaces between JCSDA models and external researchers
- Snow/sea ice emissivity model – permits 300% increase in sounding data usage over high latitudes – improved polar forecasts
- MODIS winds, polar regions, - improved forecasts - Implemented
- AIRS radiances assimilated – improved forecasts – Implemented
- COSMIC data assimilated – improved forecasts - Implemented
- Improved physically based SST analysis - Implemented
- Advanced satellite data systems such as DMSP (SSMIS), CHAMP GPS, WindSat tested for implementation.
- Data denial experiments completed for major data base components in support of system optimization

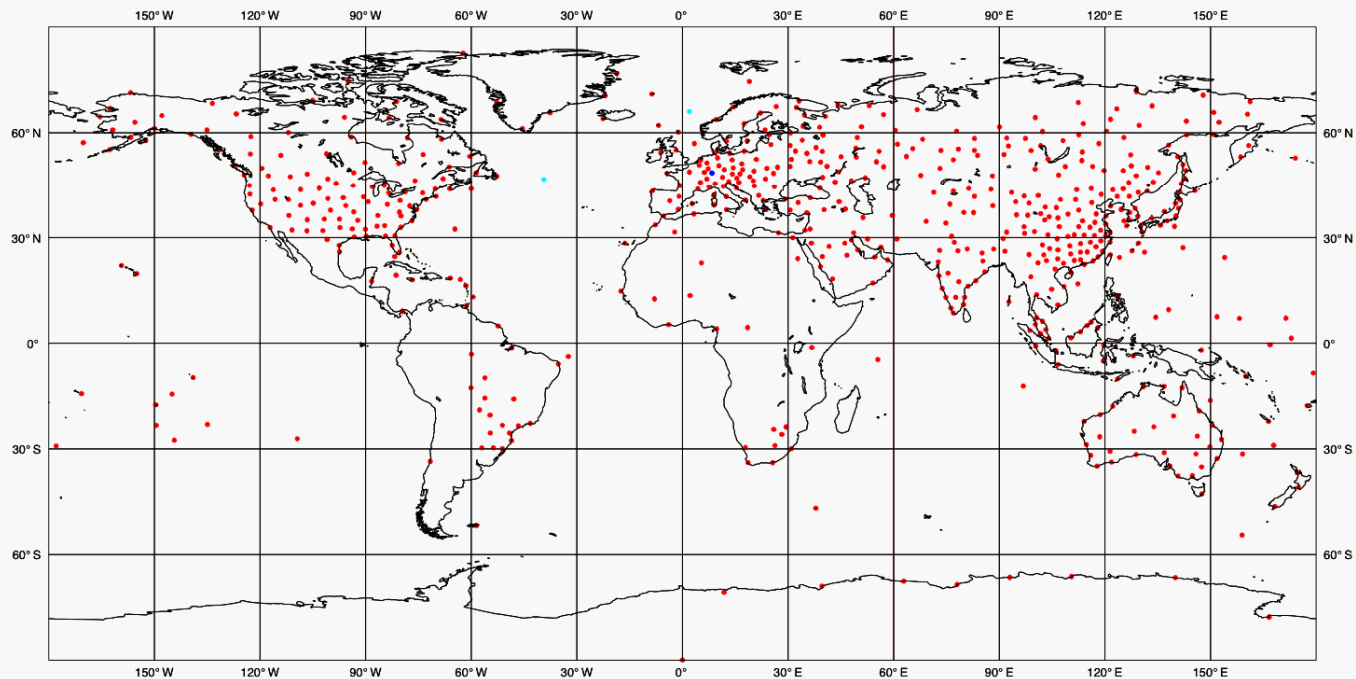
NWP requirements for upper-air data coverage



Conventional obs (u, v, T, q, vertically resolved)

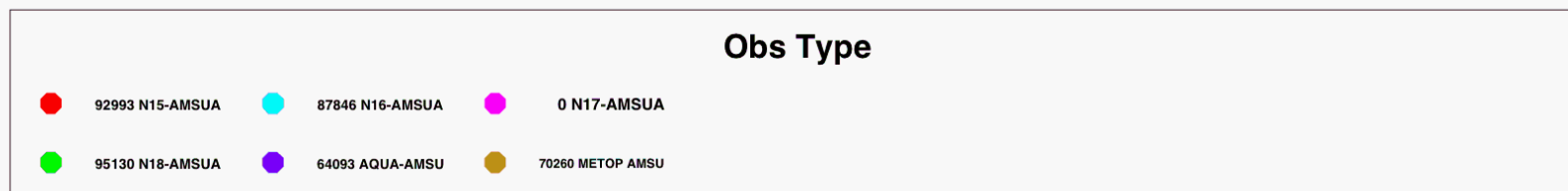


ECMWF Data Coverage (All obs DA) - TEMP
30/SEP/2007; 00 UTC
Total number of obs = 619



ECMWF

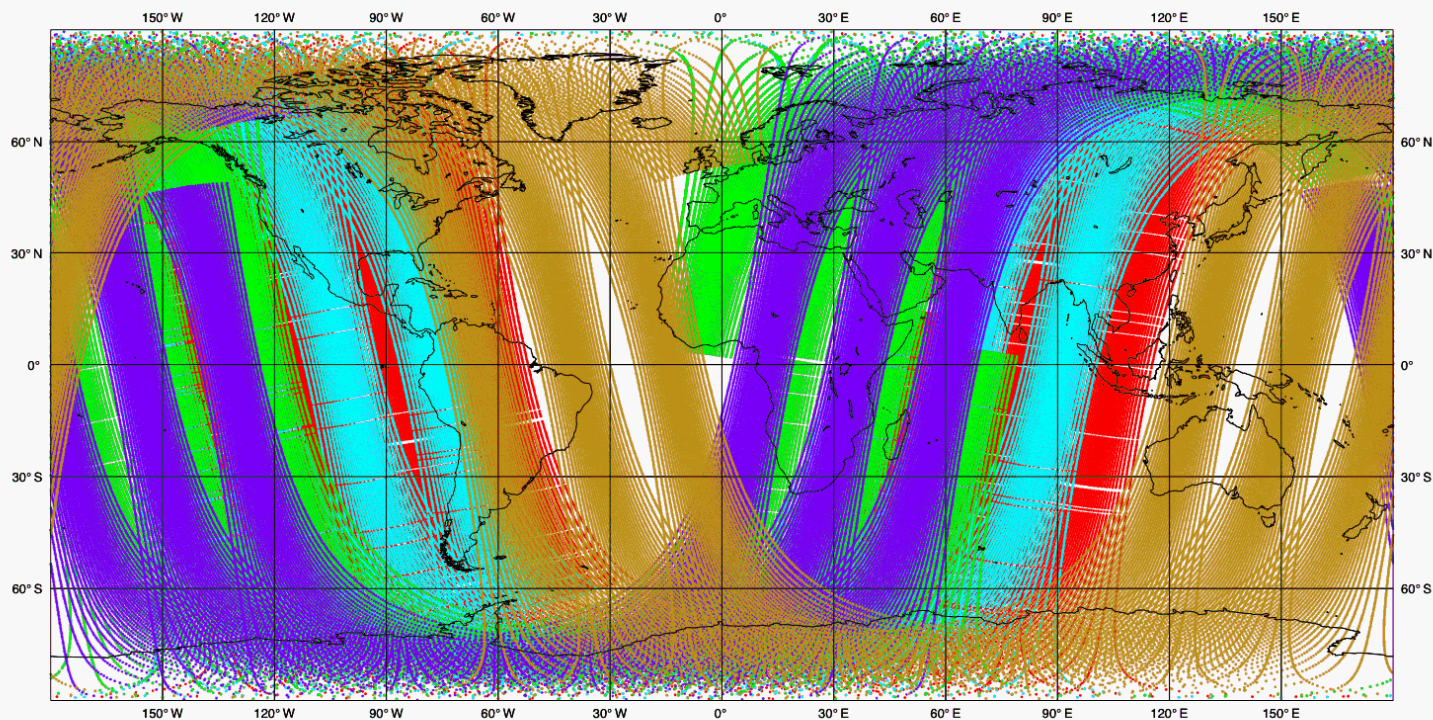
Example satellite data coverage (AMSU-A)



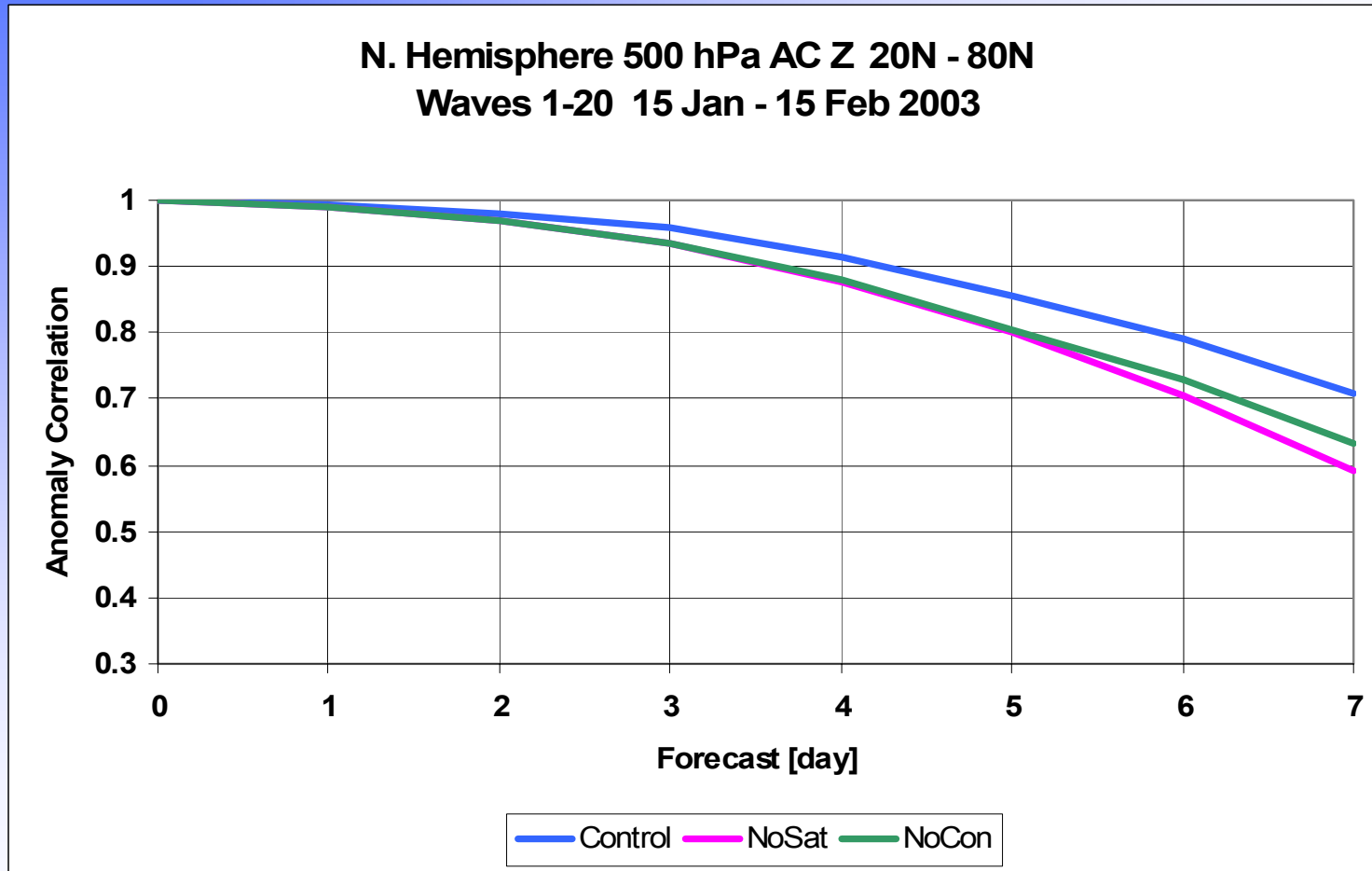
ECMWF Data Coverage (All obs DA) - ATOVS

30/SEP/2007; 00 UTC

Total number of obs = 410322



Data Assimilation Impacts in the NCEP GDAS



Satellite and Conventional data provide nearly the same amount of improvement to the Northern Hemisphere.

**N. Hemisphere 500 mb AC Z
20N - 80N Waves 1-20
1 Jan - 27 Jan '04**

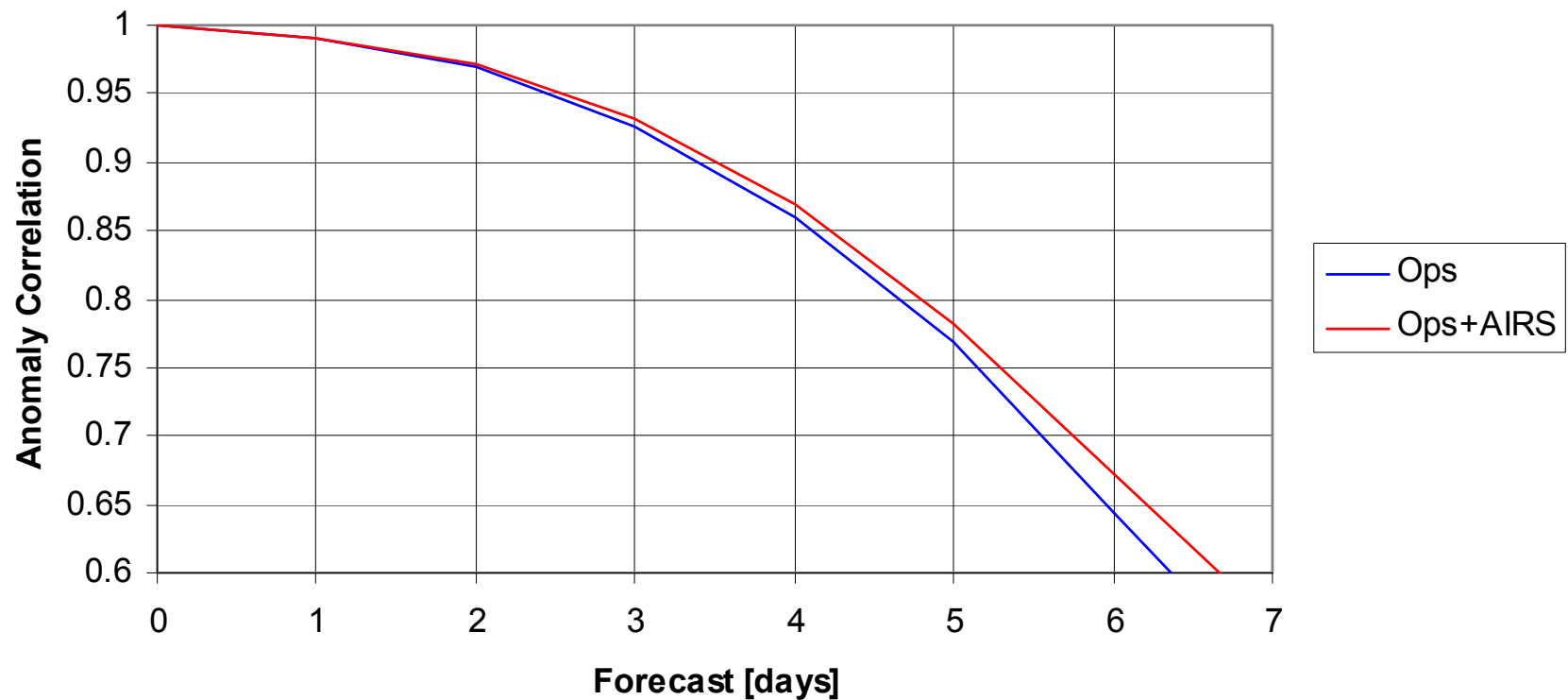


Figure 3(b). 500hPa Z Anomaly Correlations for the GFS with (Ops.+AIRS) and without (Ops.) AIRS data, Northern hemisphere, January 2004

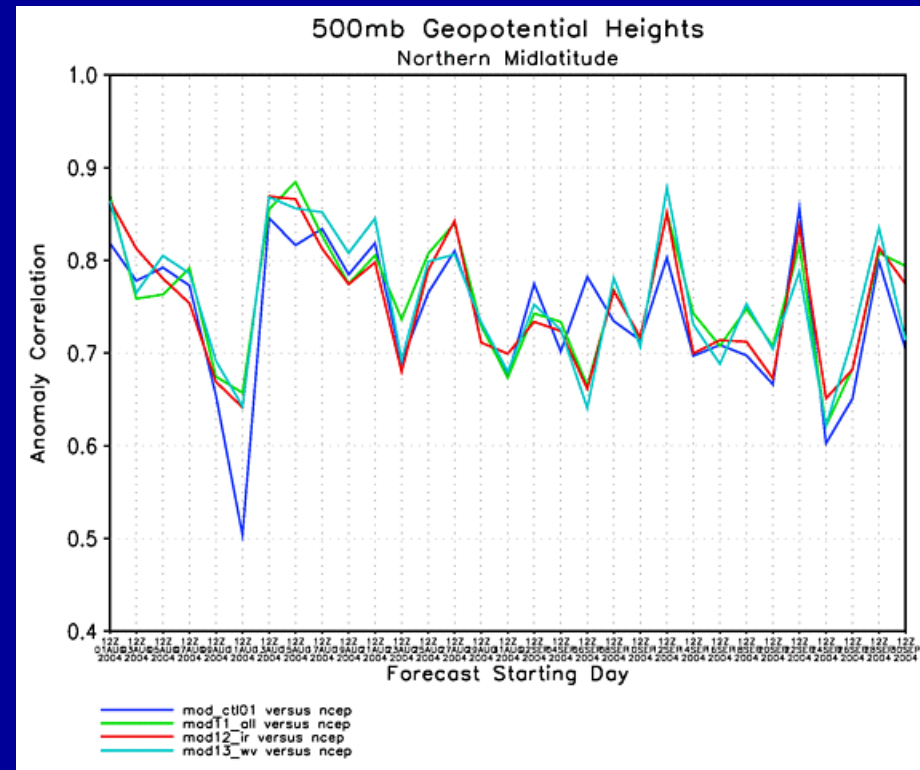
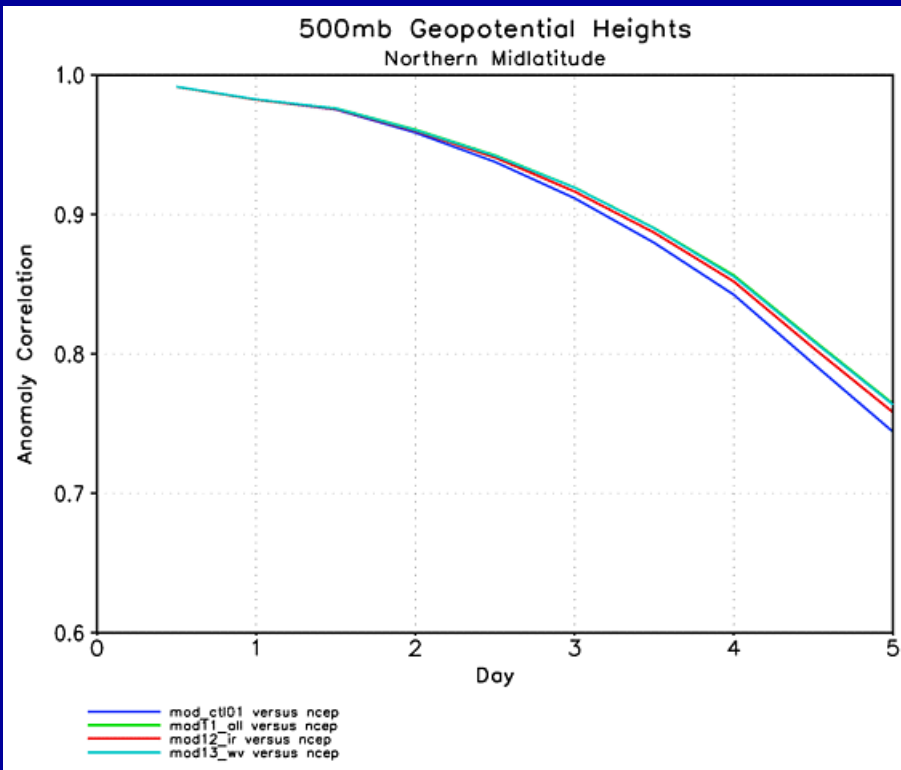
Value of weather forecasting

- Department of Commerce: “20% of overall US economy is weather sensitive”: *~\$2.8 trillion/year*
- Assume that half of this is “forecast sensitive”: *\$1.4 trillion/year*

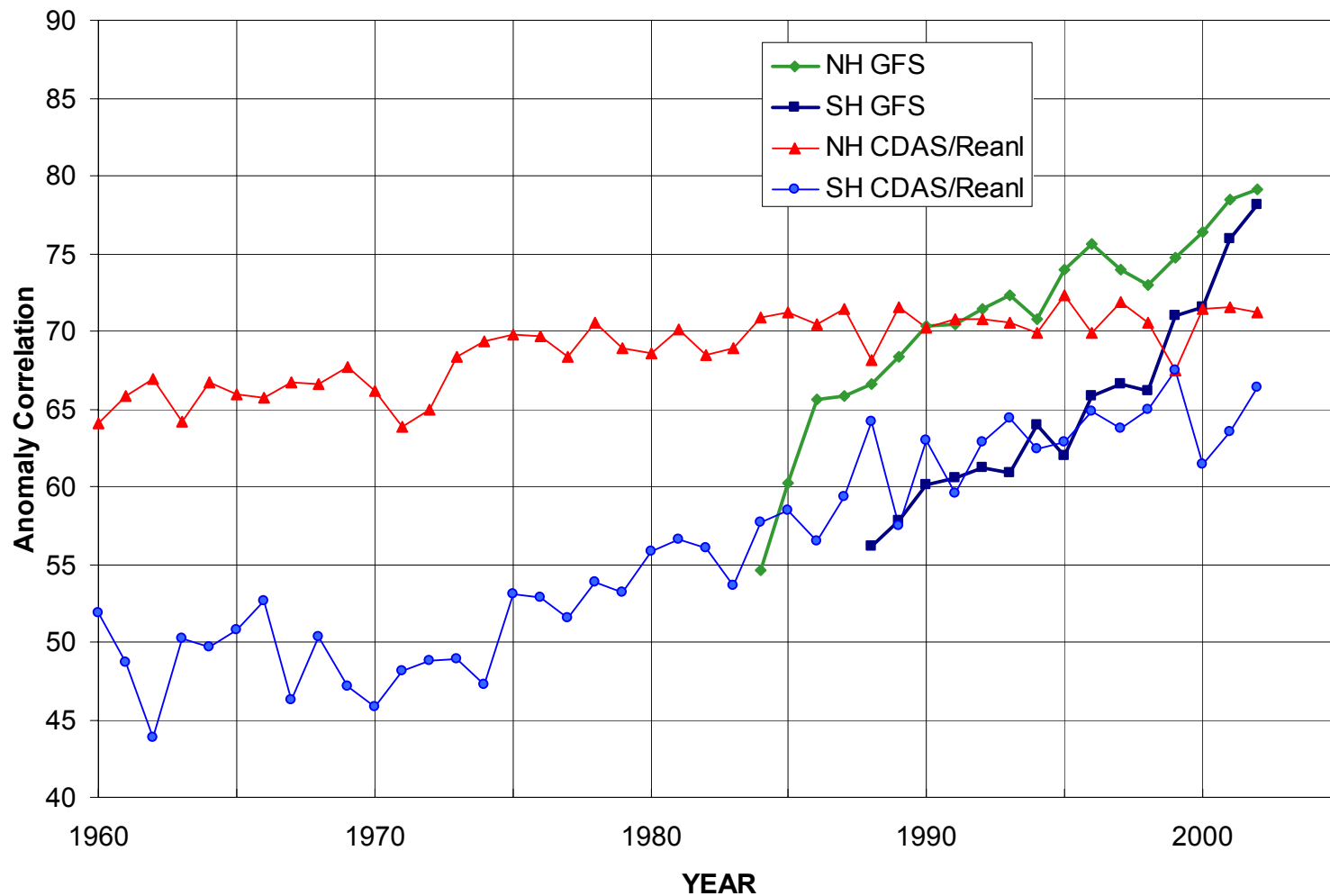
Value of weather forecasting (II)

- Assume that the potential savings due to weather forecasting amount to 5% of the “forecast sensitive total”:
~\$70B/year
- Assume that the savings are distributed linearly over the achieved forecast range for the global NWP system:
 - 0 h useful forecast range => \$0 in savings
 - 336 h useful forecast range => \$70B in savings
- This implies that the value to the United States economy of NWP is *~200M per hour of forecast range per year !*

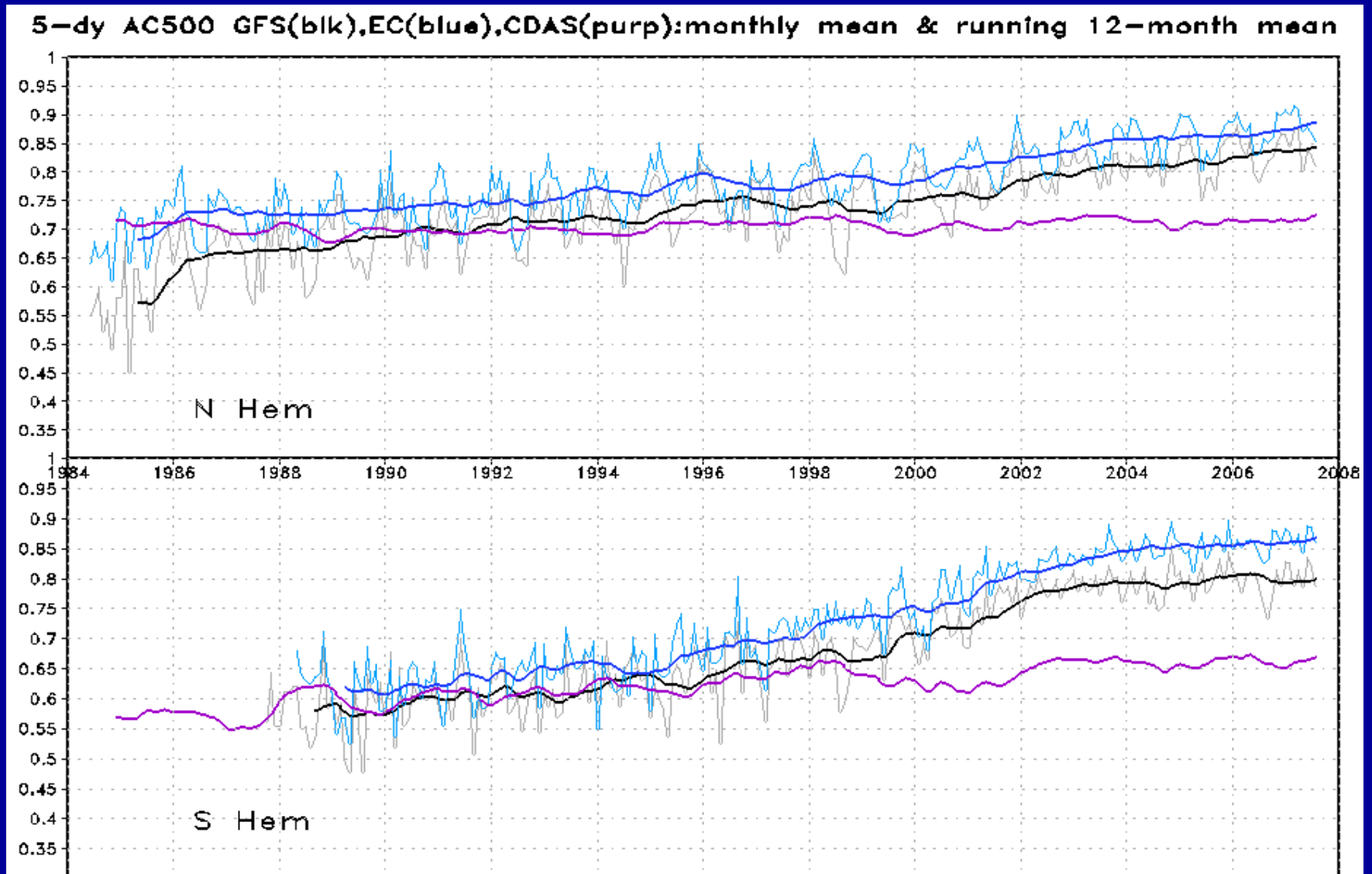
MODIS winds in GEOS-5

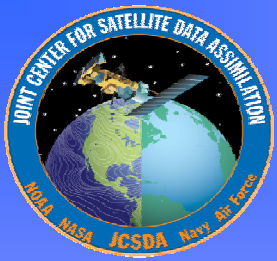


CDAS/Reanl vs GFS
NH/SH 500Hpa day 5
Anomaly Correlation (20-80 N/S)



NOAA/NCEP vs. ECMWF skill over 20+ years



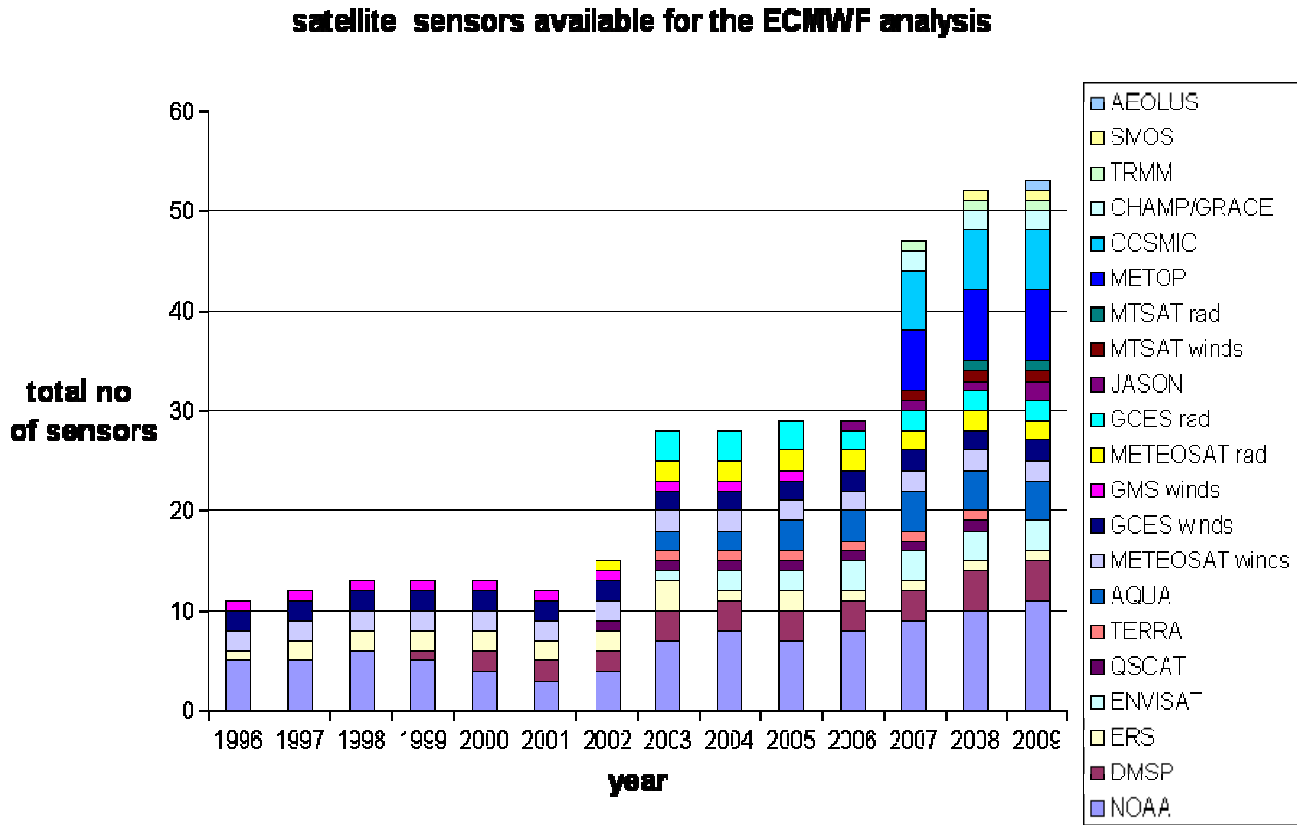


Satellite Data used in NWP

- **HIRS sounder radiances**
- **AMSU-A sounder radiances**
- **AMSU-B sounder radiances**
- **GOES sounder radiances**
- **GOES, Meteosat, GMS winds**
- **GOES precipitation rate**
- **SSM/I precipitation rates**
- **TRMM precipitation rates**
- **SSM/I ocean surface wind speeds**
- **ERS-2 ocean surface wind vectors**
- **Quikscat ocean surface wind vectors**
- **AVHRR SST**
- **AVHRR vegetation fraction**
- **AVHRR surface type**
- **Multi-satellite snow cover**
- **Multi-satellite sea ice**
- **SBUV/2 ozone profile and total ozone**
- **Altimeter sea level observations (ocean data assimilation)**
- **AIRS**
- **MODIS Winds**
- **COSMIC**

~33 instruments

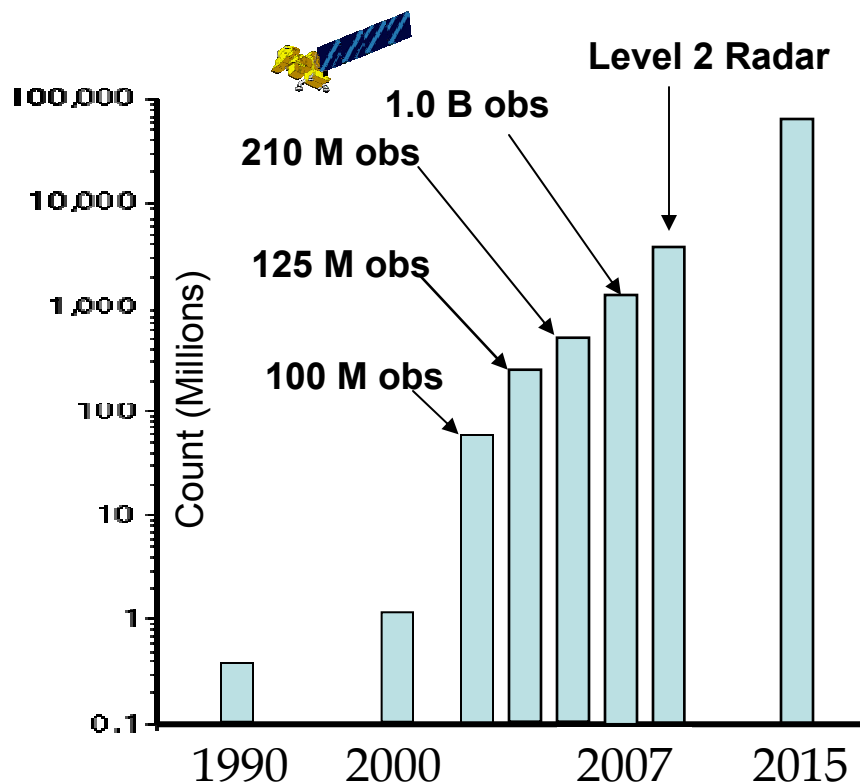
the ECMWF operational data assimilation.



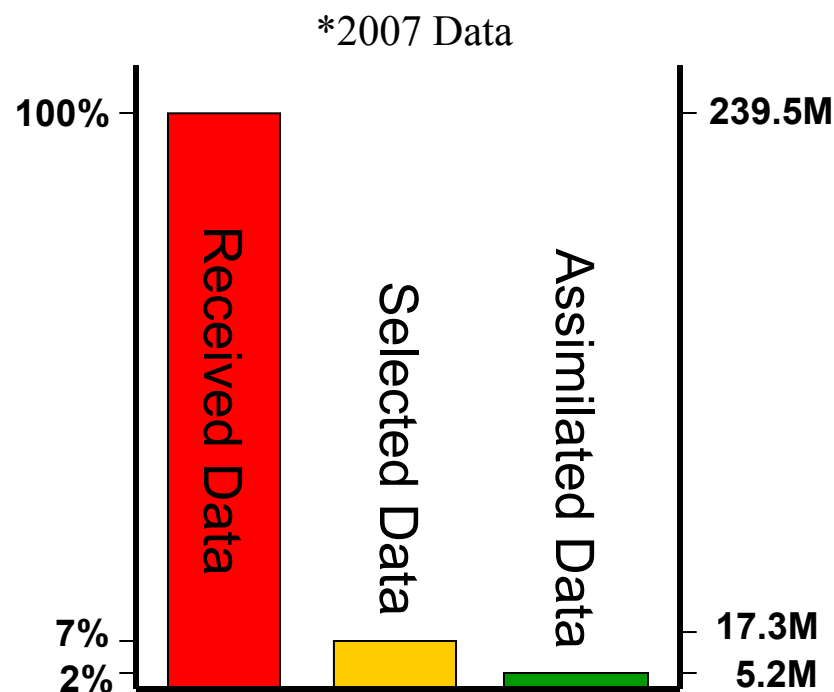
NASA-NOAA-DOD Joint Center for Satellite Data Assimilation (JCSDA)

Satellite Data Ingest

Daily Satellite & Radar Observation Count



Daily Percentage of Data Ingested into Models



Motivating Factors for the JCSDA

Five Order of Magnitude Increases in Satellite Data Over Fifteen Years (2000-2015)

Received = All observations received operationally from providers
Selected = Observations selected as suitable for use
Assimilated = Observations actually used by models

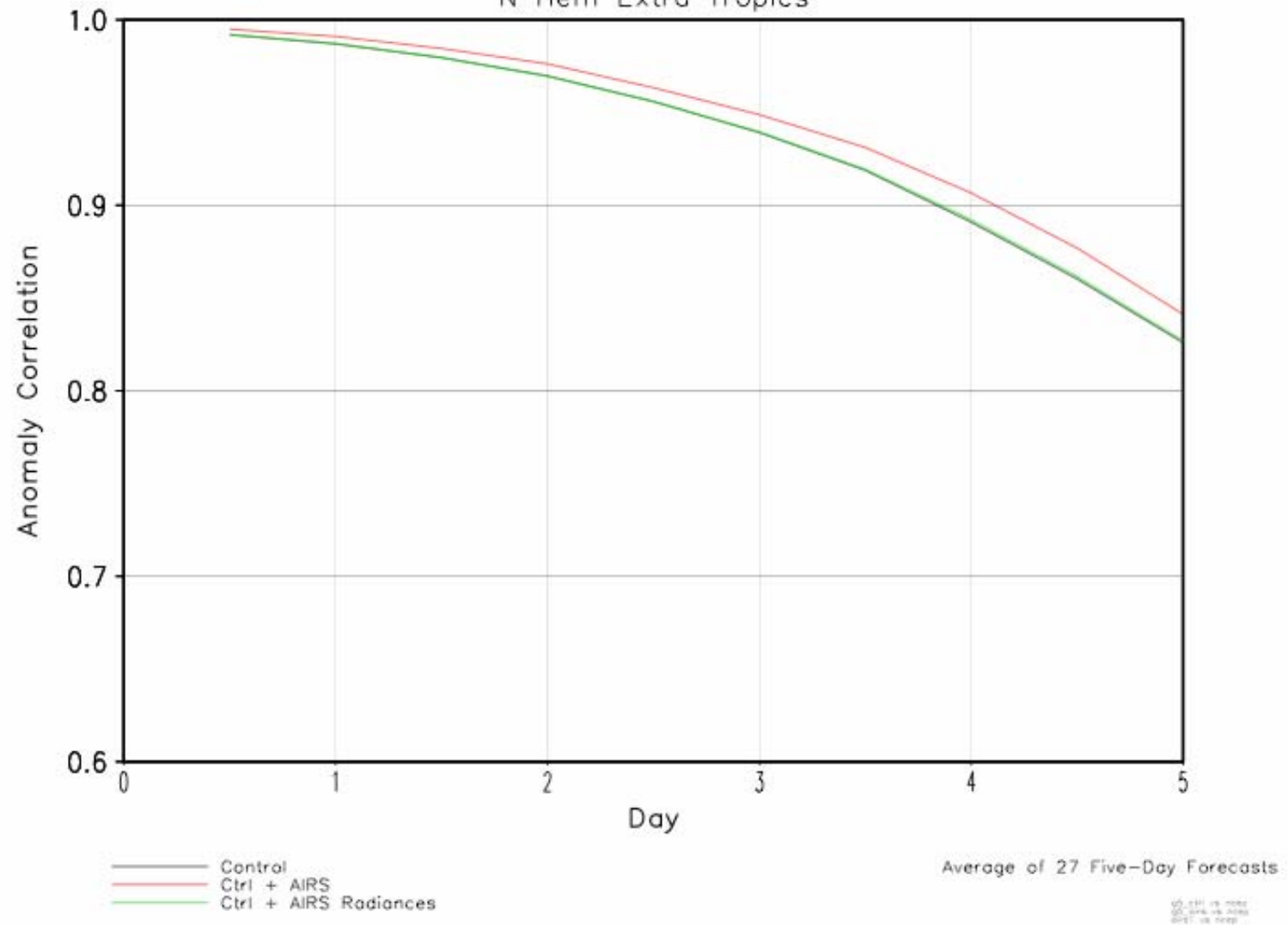
Too many observations, or not enough?

- AIRS
 - > 3 billion radiance measurements/day
 - ~100 million received
 - ~2 million assimilated
- Data volume creates logistical and scientific problems
- Clouds
- HDTV analogy
 - > 200 billion pieces of information per day per channel; device is arguably useful even if user not glued to it 24/7
 - Similarly, not every piece of information provided has to be assimilated in order for AIRS to be a success; focus on the breaking news!

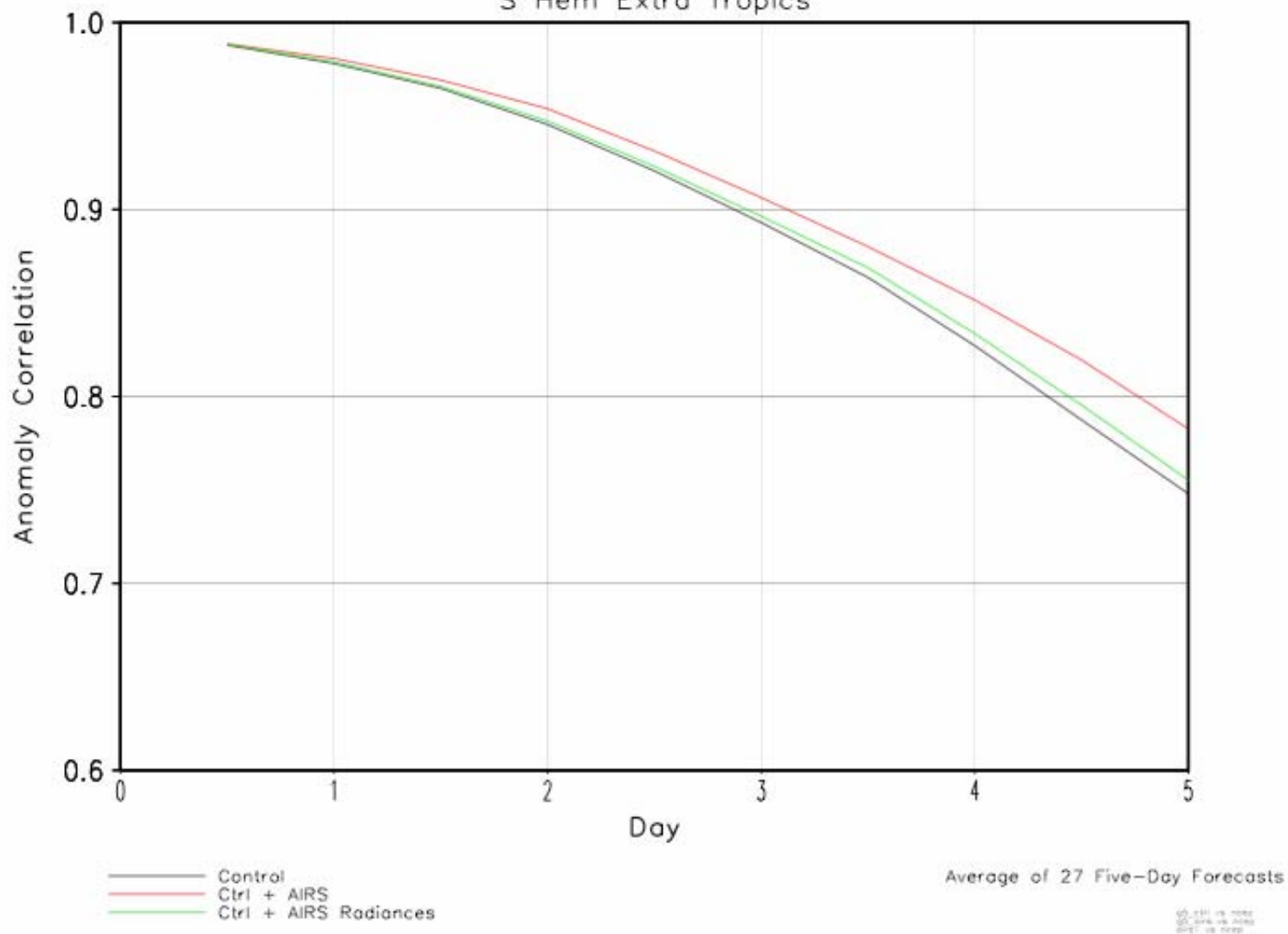
AIRS radiance vs. retrievals comparison

- One period (January 2003), three experiments:
 - Control; including all observations used for routine operations: radiosonde, surface, aircraft and satellite measurements
 - AIRS-1; control + AIRS clear radiances (251 channels)
 - AIRS-2; control + AIRS Science Team temperature retrievals (v. 4.7);
- Assimilation system is GEOS-5, beta7p4; horizontal resolution 1 by 1 $\frac{1}{4}$ degrees
 - fv-model
 - GSI analysis
 - radiance-based system; AIRS retrievals assimilated as if they were radiosondes
- 27 cases: five-day forecast every day at 00Z; verification carried out against self and NCEP operational analysis (only NCEP shown here)

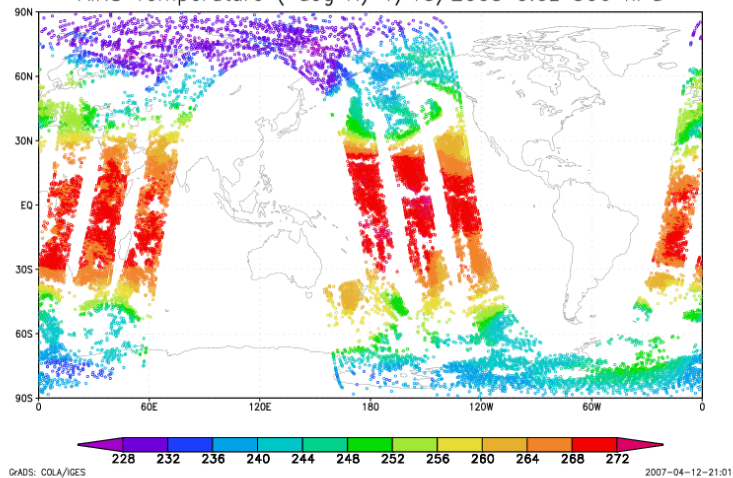
500mb Geopotential Heights N Hem Extra Tropics



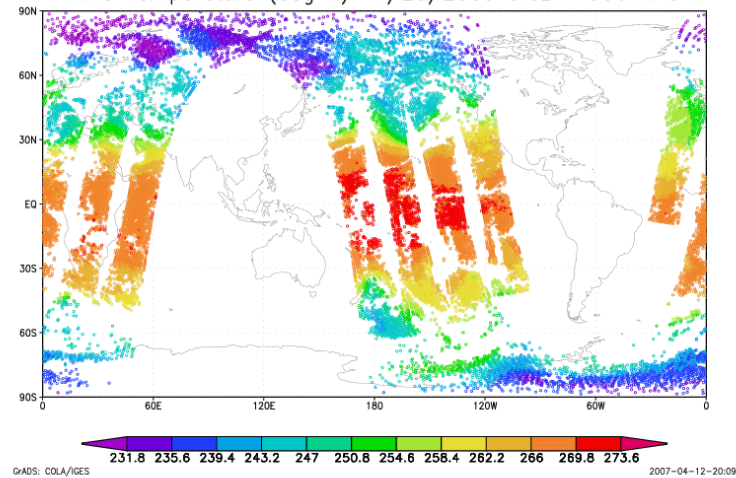
500mb Geopotential Heights S Hem Extra Tropics



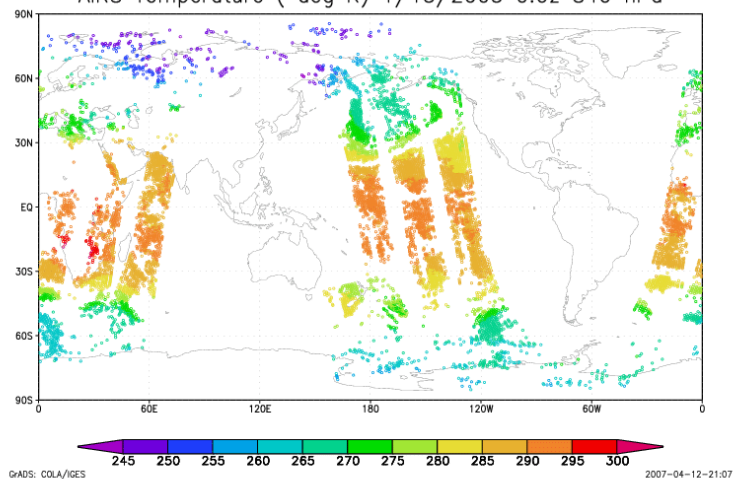
AIRS Temperature (deg K) 1/15/2003 0.0z 506 hPa



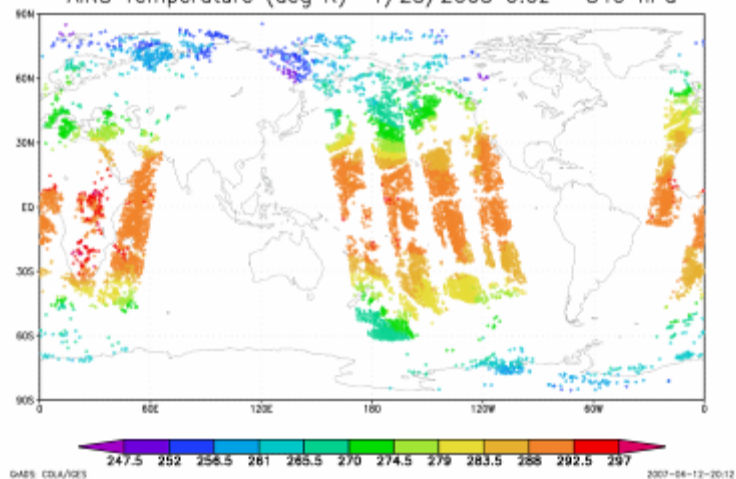
AIRS Temperature (deg K) 1/25/2003 0.0z 506 hPa



AIRS Temperature (deg K) 1/15/2003 0.0z 840 hPa

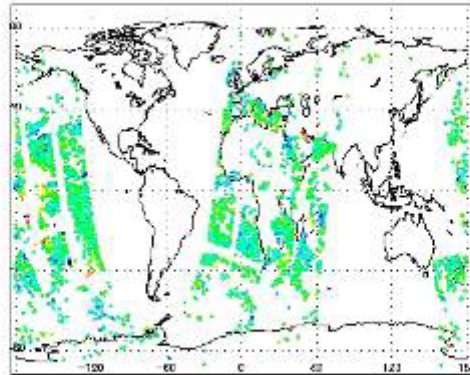


AIRS Temperature (deg K) 1/25/2003 0.0z 840 hPa

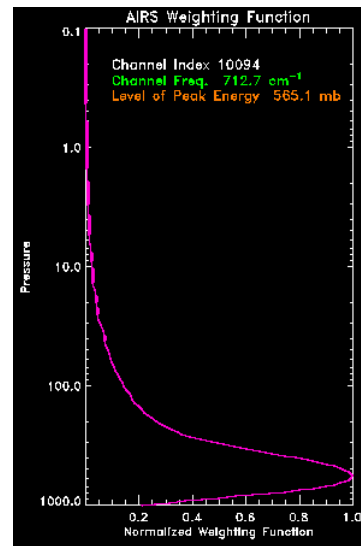
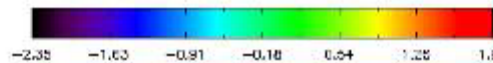


Radiances Used in Analysis for Two Low Peaking Tropospheric AIRS Channels

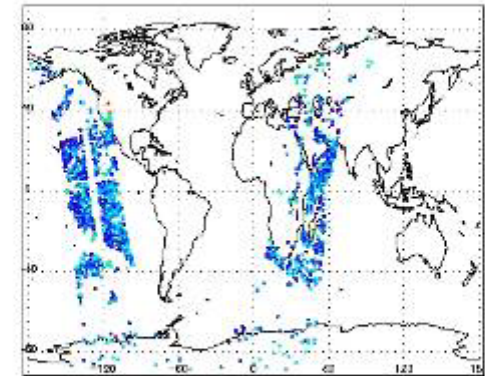
Simulated (w/ Bias Correction) - Observed T_b (%) AQUA AIRS 20030115 00Z
 ** Assimilated Accepted Global All Src. All Day gas airt



Channel 221 Freq 712.7 cm⁻¹ Nobs 2390 Avg. -0.15 Std. 0.45



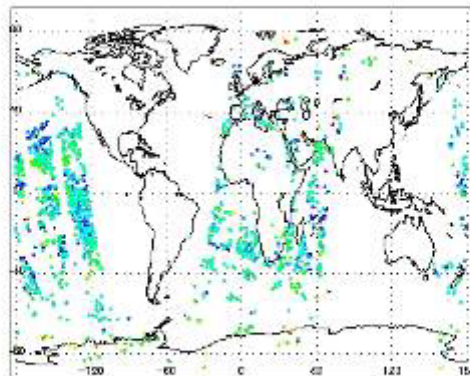
Simulated (w/ Bias Correction) - Observed T_b (%) AQUA AIRS 20030125 00Z
 ** Assimilated Accepted Global All Src. All Day gas airt



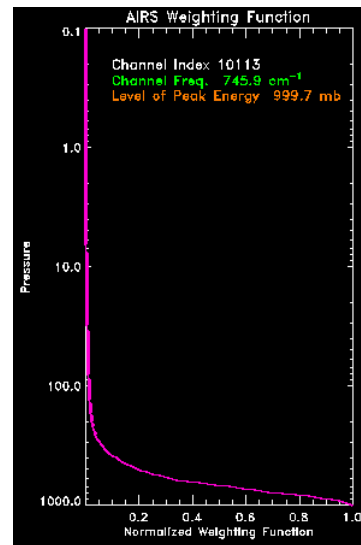
Channel 221 Freq 712.7 cm⁻¹ Nobs 1278 Avg. -0.12 Std. 0.40



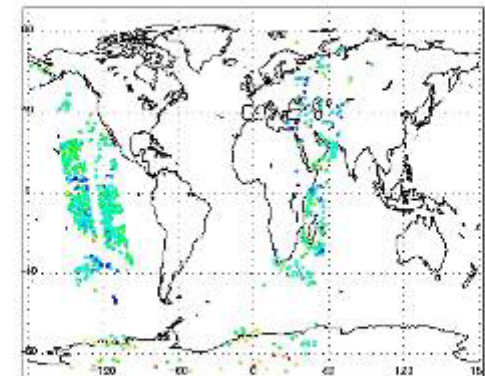
Simulated (w/ Bias Correction) - Observed T_b (%) AQUA AIRS 20030115 00Z
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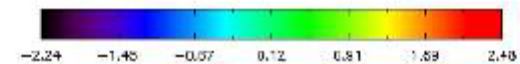
Channel 333 Freq 746.0 cm⁻¹ Nobs 1260 Avg. -0.12 Std. 0.53



Simulated (w/ Bias Correction) - Observed T_b (%) AQUA AIRS 20030125 00Z
 ** Assimilated Accepted Global All Src. All Day gas airt

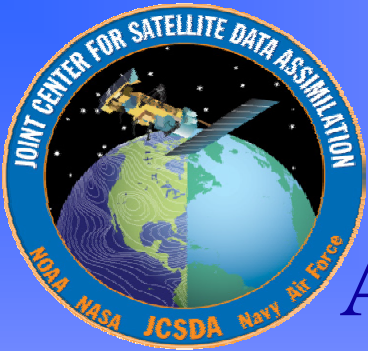


Channel 333 Freq 746.0 cm⁻¹ Nobs 743 Avg. -0.044 Std. 0.58



20030115 00z

20030125 00z

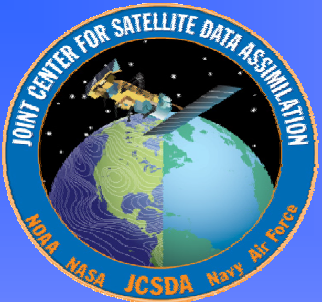


AIRS Data Assimilation Using Cloudy Fields of View

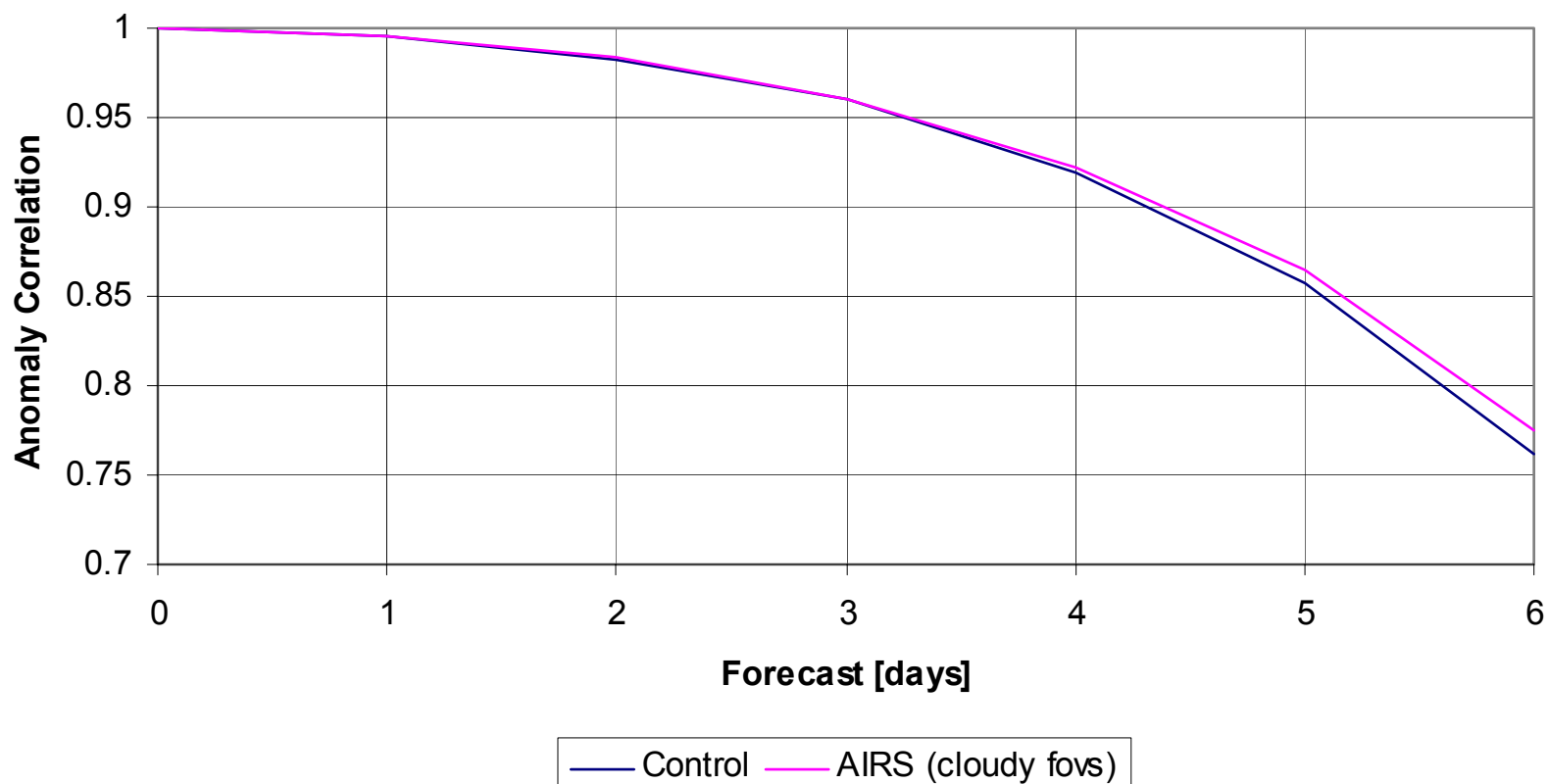
Initial Experiments: 1 January – 24 February 2007

**Control – Current Ops. (OP. data coverage - Uses
152 AIRS channels from all fovs with operational
thinning)**

**Experiment- Op. data coverage, minus Op. AIRS
plus AIRS radiances from channels free from cloud
effects and radiances from the clear air part of
selected cloudy fovs (with operational thinning).**



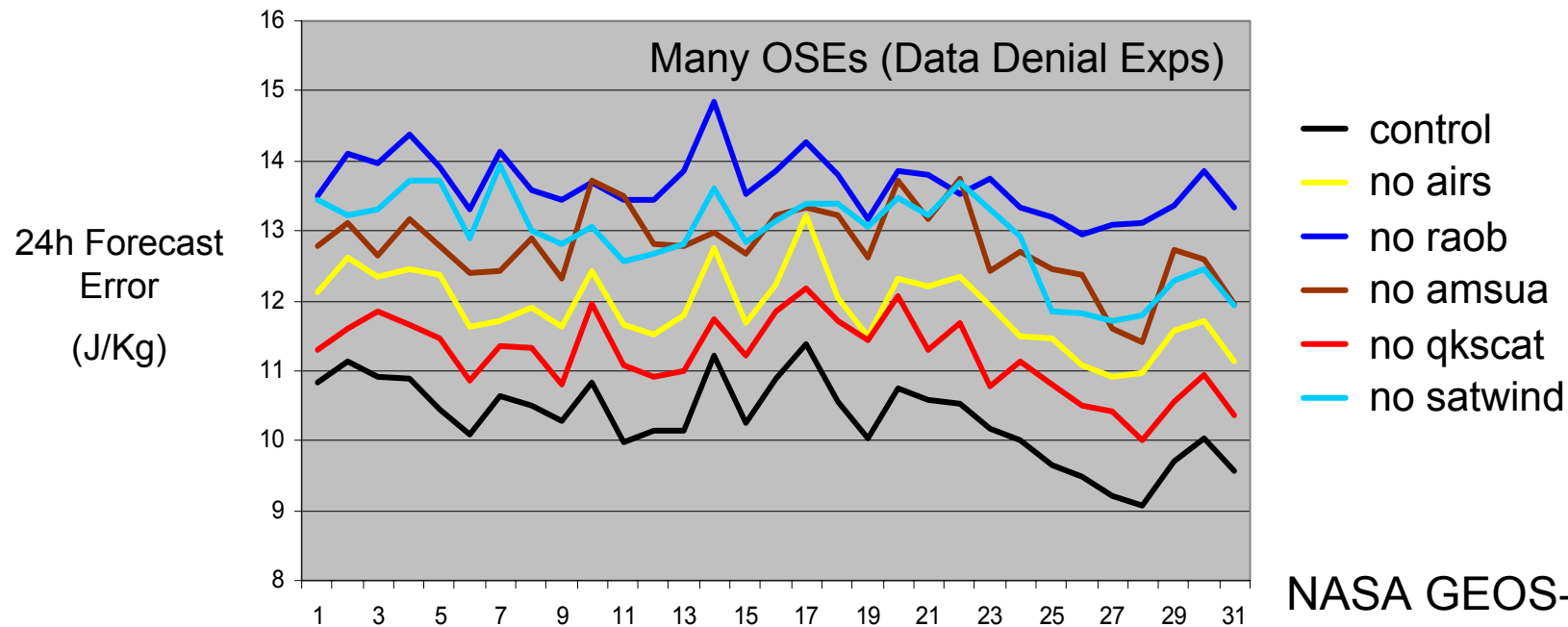
N. Hemisphere 500 hPa AC Z 20N - 80N Waves 1-20
1 Jan - 24 Feb '07



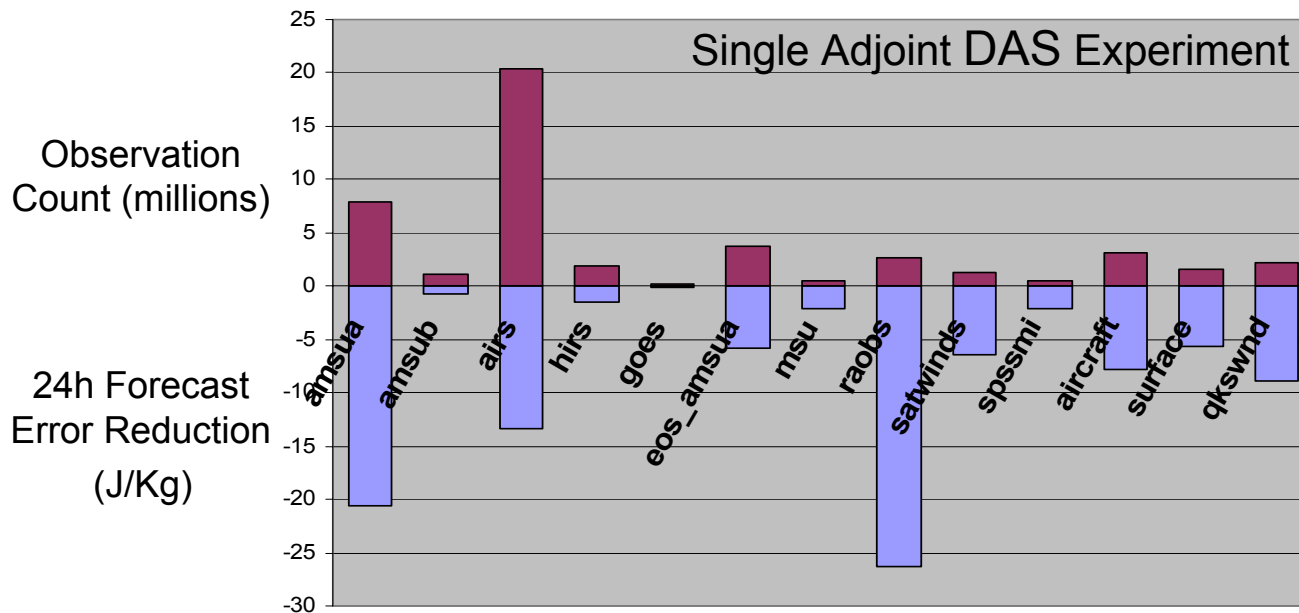
How do we measure data impact?

- Classical data denial experiment (OSE)
 - Highlights the effects of pulling out whole classes of observations on a wide variety of diagnostics
- Emerging technique: Adjoint sensitivity analysis (Gelaro, Langland, Baker, Daley, ...)
 - Highlights the impact of a pre-defined metric (cost function) observation by observation

Efficient Estimation of Observation Impact



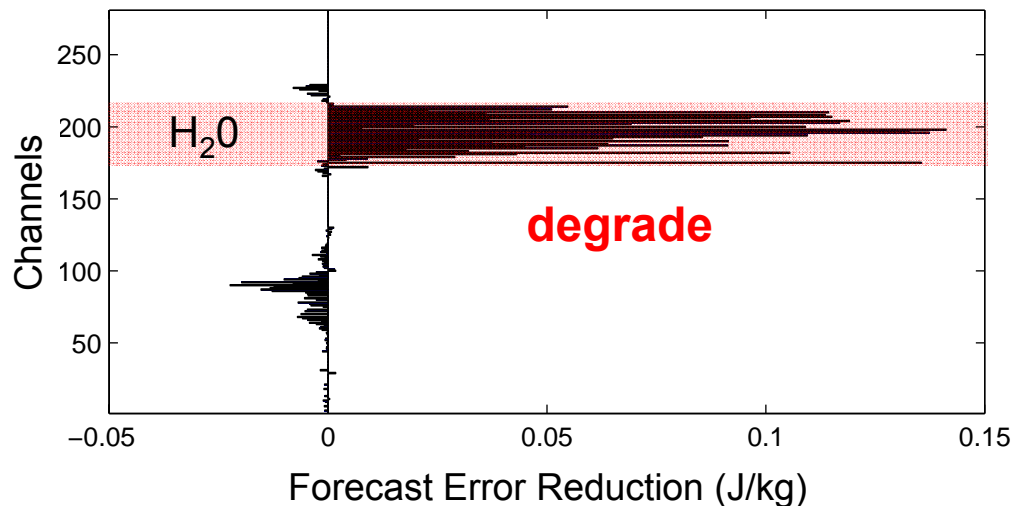
NASA GEOS-5
July 2005 00z



Adjoint examination of AIRS negative impact

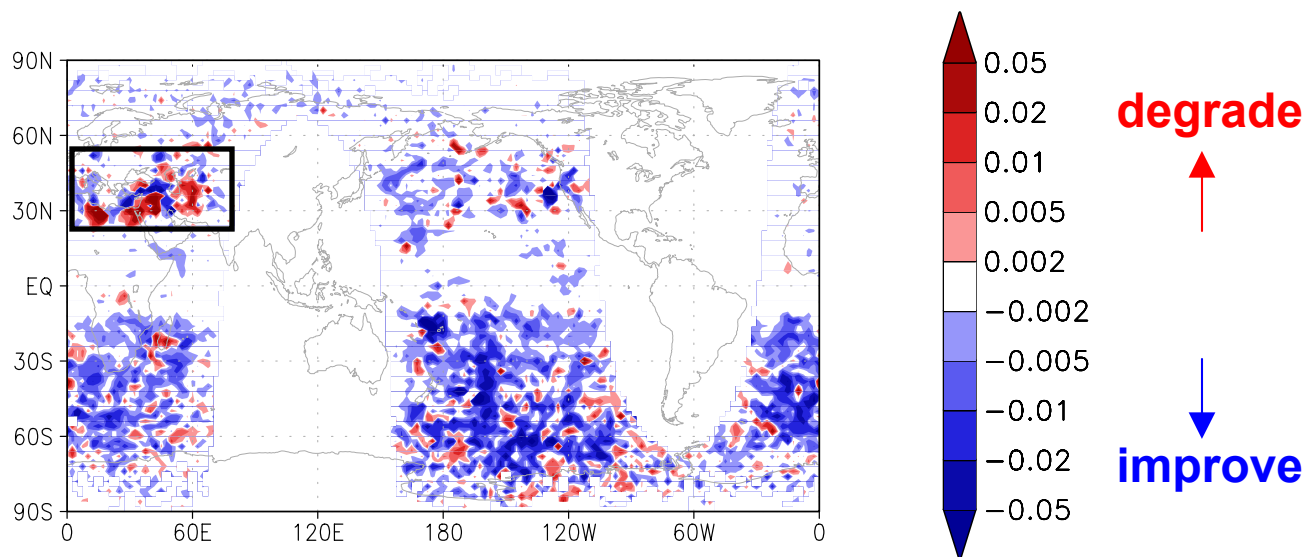
July 2005 00z (20-50N, 0-80E)

AIRS
impact by
channel



Subsequent removal
of AIRS **water
vapor channels**
improved the
forecast scores

AIRS
impact map



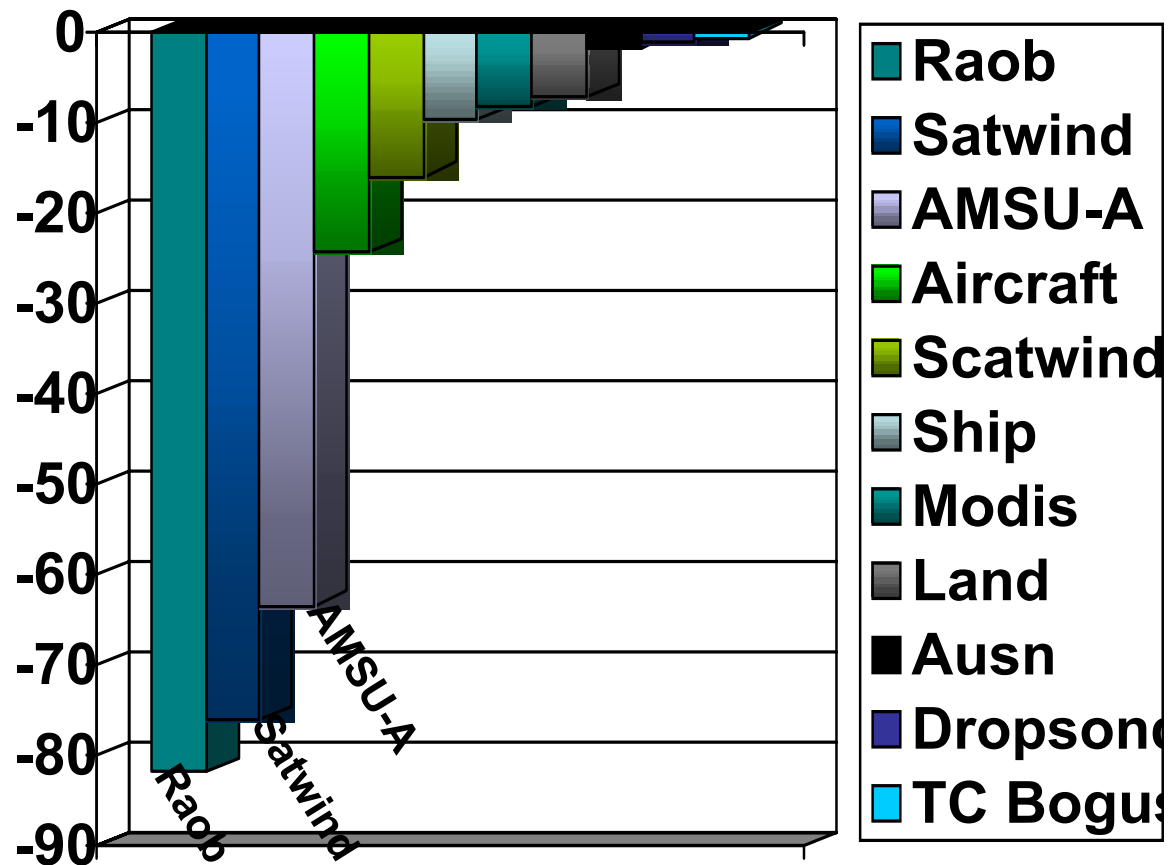
NAVDAS ADJOINT

Total Impact by Observation Type

Units of impact = J kg^{-1}

1 Jan – 28 Feb 2006
00UTC Analysis

Beneficial
impact



What next?

- Operational implementation plan
- Data assimilation system development
- Launch schedules
- OSSE capability

Operational implementation plans (NCEP/EMC):

- | | |
|--------------------------|------------------|
| • Windsat | 3rd Q FY08 |
| • IASI | 4th Q FY08 |
| • ASCAT | “ |
| • COSMIC (bending angle) | “ |
| • OMI ozone | “ |
| • SSMI/S | “ |
| • GRAS | (date still TBD) |
| • Sat winds EE screening | “ |
| • GOME-2 | “ |

Meanwhile ...

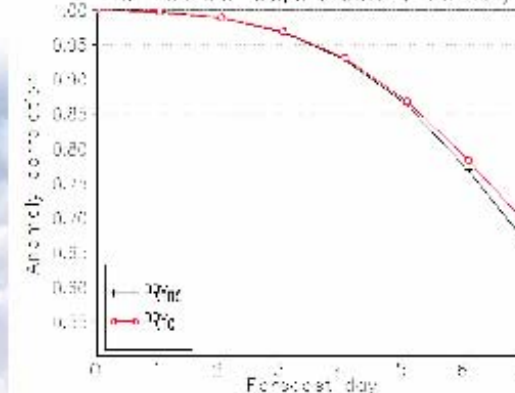
- IASI operational at ECMWF since June 12, 2007; ASCAT a close second
- JCSDA lagging by one year; lack of planning and resources
 - DDS, timeliness, CRTM readiness ...
- JCSDA will have to invest heavily in NPP and ADM now in order to prevent this from happening again
 - Simulated data need to be flowing into a replica of the operational assimilation well before launch

GSI/GFS Impact study with COSMIC

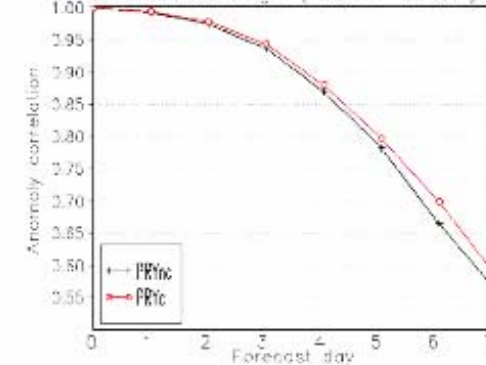


- Anomaly correlation as a function of forecast day for two different experiments:
 - PRYnc (assimilation of operational obs),
 - PRYc (PRYnc + COSMIC refractivity)
- We assimilated around 1,000 COSMIC profiles per day
- In general, the impact of the COSMIC data will depend on the meteorological situation, model performance, location of the observations, etc.

AVERAGE FOR 00Z01NOV2006 – 00Z30NOV2006
SH 500 mb Height (wave 1–20 AC)



AVERAGE FOR 00Z01NOV2006 – 00Z30NOV2006
SH 500 mb Height (wave 1–20 AC)



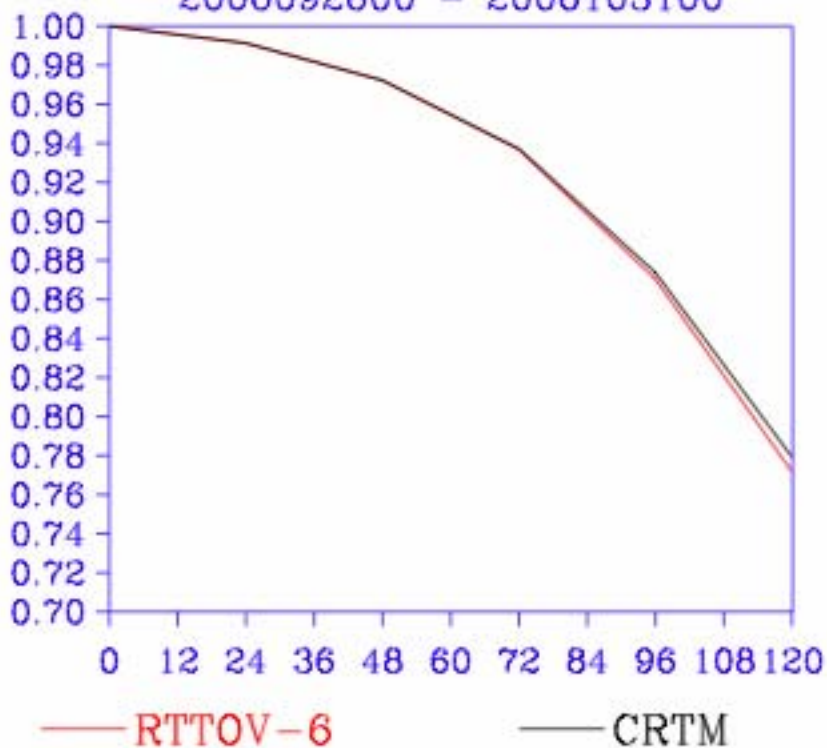
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.



"CRTM" Impact

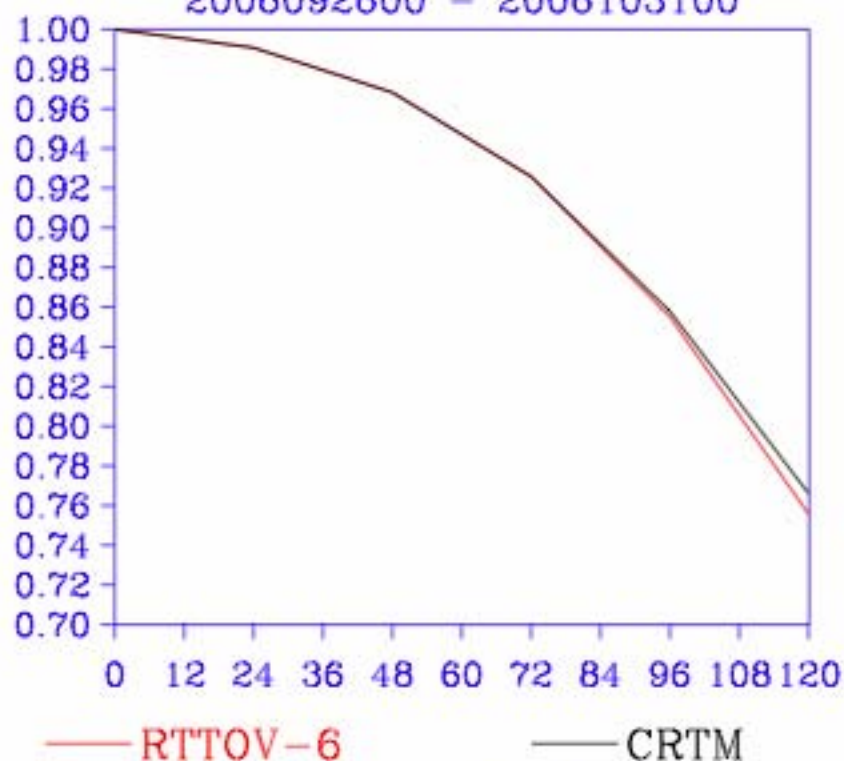
500 mb Height Anomaly Correlation

NOGAPS DATA ASSIMILATION TEST
500 MB NORTH HEM HEIGHT ANOMALY COR
2006092600 - 2006103100



Northern Hemisphere

NOGAPS DATA ASSIMILATION TEST
500 MB SOUTH HEM HEIGHT ANOMALY COR
2006092600 - 2006103100



Southern Hemisphere

September 26 - October 19, 2006

Next-generation data assimilation system(s)

- JCSDA needs a four-dimensional data assimilation system
 - Satellite data are inherently asynoptic
 - Modern algorithms (4D-VAR, ensemble-based) have explicitly or implicitly state-dependent and multivariate background error covariances
 - 4D-VAR is the algorithm to beat

System development challenges

- GSI now operational at NCEP (May 1, 2007)
 - Simplified 4D-VAR (“FOTO”) in testing
- GMAO validating GSI-based system for reanalysis; operations will follow shortly
 - Classical 4D-VAR in advanced stages of development
- AFWA/NCAR using WRF/VAR
 - 3D-VAR and 4D-VAR options; GSI under implementation
- NRL/Monterey using NAVDAS; “4D” version (Accelerated Representer) in testing

Short-term challenge for the JCSDA:

- Very aggressive satellite launch schedule
 - 2008 - SMOS, DMSP F-18, GOES O, GOCE, GOSAT, Jason-2
 - 2009 - OCO, ADM, Aquarius, NPP (CrIS, VIIRS, ATMS, CMIS), NOAA N', MSG-3, GOES P, Cryosat-2
 - 2010 – DMSP F-19
 - 2011 - METOP-B, MSG-4

Long-term challenge for the nation

- A remarkably thin satellite launch schedule
 - 2010 - DMSP F-19
 - 2011 -
 - 2012 -
 - 2013 - NPOESS C-1
 - 2014 - GOES-R
 - 2015 -
- What is happening to US leadership in Earth Observations?
 - Tight funding
 - Transition from being engineering-driven to requirements-driven without a well-defined process to support this

Planned capability: Observing System Simulation Experiments (OSSE)

- NESDIS needs this for mission assessment
 - GOES-R
 - Scatterometer
 - NPOESS, NPOESS+
 - Doppler Wind Lidar
 - Non-satellite observation
- NASA needs this for mission assessment
 - Decadal survey missions
 - New opportunities

What is an OSSE system?

- *a simulated environment in which a quantitative assessment can be made of the expected impact of a hypothetical future observing system on an environmental prediction problem*

What is required?

- A simulation of reality (“Nature Run”)
- A set of simulated observations
- State of the art data assimilation system(s)
- A broad-based group of investigators collaborating using (informal “Joint OSSE” Working Group has been meeting for 18 months)
 - One methodology
 - One set of metrics
- Agency commitment and funding
 - Plan to be presented to NASA and NOAA/NESDIS this fall